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Potential Impact of Climate Change on Hydropower Generation in Southern Taiwan

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Abstract

The purpose of this study is to analyze the impact of climate change on Taiwan's hydroelectric generating capacity based on the river discharge of the GWLF simulations which were carried out by using rainfall and temperature data from four GCMs. The river discharge change of kaoping river under climate change scenarios A2 and B2 was used to assess the climate change impact on hydropower generation. The results indicated that the range of river discharge variation was -26%-15% in the dry season and -10-82% in the wet season. The potential impact on hydropower generation can be roughly estimated as the previous discharge variation.

Keywords: Climate change, hydropower, rainfall, precipetation

1. Introduction

Hydropower is a source of clean renewable energy, and it does not produce any greenhouse gas emissions.However, there are social, environmental, and economic impacts associated with harnessing hydropower. Hydropower has been heavily exploited in most developed countries with countries like the USA at 70% capacity. Hydropower is often the key to economic success in developing countries.

Presently, hydropower is one of the world's major sources of renewable energy. It accounts for approximately 20% of the electricity generated in the world. Some countries draw most of their electricity from hydropower. This is the case in Norway, Brazil, and Canada where 98.9%, 83.4%, and 57.9% of electricity generated comes from hydropower, respectively. Hydropower potential varies greatly among countries with China, India, Russia, and Brazil having the most [1]. For example, Brazil's installed

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capacity was 64.05 GW in 2005, and the country has an estimated total hydroelectric potential of 260.09 GW. China has an even greater hydroelectric potential estimated at 694 GW with 402 GW determined to be economically exploitable.

In Taiwan, 3.9% of country's total electricity was generated by hydropower in 2009[2]. Taiwan is heavily dependent on imported fossil fuels and 99% of energy supply was imported that year. Thus, it is important that Taiwan moves towards sources of renewable energy for electricity generation. Despite these issues, hydropower can still provide and important link to a new energy future for Taiwan. However, social, ecological, and economic impacts must be considered thoroughly and minimized during the planning, construction, and operation of any new hydropower plants.

Climate change can have a serious impact on river discharge and hydropower generation. In recent years, a number of studies have been conducted to assess climate change impact on river discharge or water resource [3, 4, 5]. The change of river discharge will influence the hydropower generation.

2. Electricity needs in Taiwan

Taiwan's average load for the year 2010 was 26.979 GW with a peak load of 33.023 GW. Taiwan's rapid industrialization and economic growth between the 1950s and the 1990s is often referred to as the Taiwan Miracle. During this period, Taiwan's economy shifted from agriculture, to industry, and finally to electronics and information technology. Taiwan is currently a leading manufacturer of information technology and is a heavily industrialized country. Energy and industry consumed 60.35% of Taiwan's electricity in 2010[6].

Increased industrialization also leads to increased disposable income and increased electricity usage. Electricity demand on the island is lowest in February and peaks during the months of July and August. This corresponds to winter and summer respectively, and electricity use is directly correlated with climate and temperature. Taiwan's climate ranges from subtropical in the north to tropical in the south. Summers are hot and humid, and the average temperature during the summer is about 27°C. Northern Taiwan gets hotter than the south during the summer and temperatures in Taipei can get up to 35°C (95°F). Thus, air conditioning units are ubiquitous in Taiwan and can account for 30% of Taiwan's power consumption in the summer months. During peak load times, this percentage can jump up to 40 [2]. Taipower continued to develop and purchase renewable energy, including hydro, wind and solar power. In 2011, the newly added renewable energy installed capacity reached 107.2 MW. The CO 2 emissions were reduced by 0.195 million tons. In addition, the increase of gas-fired generation cut down CO 2 emissions by 1.1773 million tons [6]. Table 1 shows that the cost of hydropower is lower than others energy sources except nuclear power.

Table 1 Cost of various electric power generation

Cost	OECD countries NT dollar (Kw.hr)	Taiwan NT dollar (Kw.hr)
Coal	2.09～2.56	1.87
Hydropower	0.96～1.28	1.34
Nuclear power	1.87～3.16	0.62
Gas	2.74～2.95	3.54
wind power	3.10～4.39	3.22
solar power	13.15～19.73	12.97

3. Geography and Climate

Taiwan island lies on the Tropic of Cancer, and is divided into two climates: the tropical monsoon climate in the south and the subtropical monsoon climate in the north. Taiwan is affected by monsoons all

year round. The south experiences more seasonally varied rainfall, while the north experiences a wider range in temperature. The average annual temperature is about 24°C in the south. Taiwan's average annual rainfall is greater than 2,500 mm. In Taiwan, Rivers have steep slop (average:0.655). There is high potential to develop hydropower.These aspects of spatial and seasonal distribution of rainfall and climate change must be taken into consideration when implementing hydropower plants. Kaoping river basin is located at the southwest Taiwan. It mainly flows through Kaohsiung, Pingtung and etc. Its basin is the biggest in Taiwan. (see Fig 1)

4. methodology

In this study, we used the Generalized Watershed Loading Functions (GWLF) [7] hydrological model to simulate the discharge of the Kaoping River under climate change scenarios A2 and B2 as released by the Intergovernmental Panel on Climate Change (IPCC).

We discussed the potential impact of climate change on hydropower based on the results of GWLF simulations carried out using rainfall and temperature data from five General Circulation Models (GCMs).(see Fig. 2)

Fig. 1 Location map of Kaoping basin

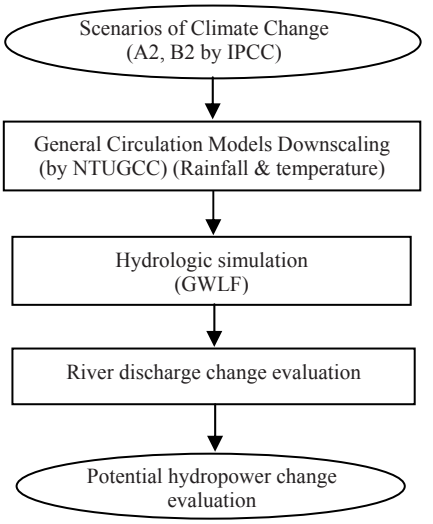

Fig.2 Flow chart of this study

4.1 Climate Change Scenarios and GCMs

The impacts under scenario A2 and B2 were discussed in this study. The downscaled data of the GCMs for the A2 and B2 scenarios were adopted from the Global Change Research Center (GCRC) in National Taiwan University, which was supported by National Science Council to develop the downscaled climate change data for Taiwan area. As per the recommendation of the IPCC, it is important to use as many as possible GCMs in a study because of the uncertainty of the long-term accuracy of GCMs. We used all the data of GCMs with both two scenarios which GCRC has done with statistical downscaling. In addition, all the data of those GCMs used in this study are highly related to local weather stations. The General Circulation Models used in this study included CCCSRNIES, CCCMA, ECHAM4, GFDL, HADCM3

5. Results and Discussions

The river discharge of Kaoping river basin was simulated in order to analyze the possible impact on hydropower in southern Taiwan in this study. The results of most of these models showed that the range of river discharge variation was -26%-15% in the dry season and -10-82% in the wet season. Climate change has the potential to alter Taiwan's hydrology and hydropower generation capacity. Some models predict more annual rainfall while others predict less. However, most agree that rainfall will become unevenly distributed spatially with precipitation increasing during the wet season and precipitation decreasing during the dry season. The potential impact on hydropower generation can be roughly estimated as the previous discharge variation.

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